Drilling Fluids for Horizontal Wells

Drilling the first horizontal wells was slow and trouble-prone, costing several times a vertical or normally offset deviated well in the same reservoir. Today, drilling a horizontal well is almost routine and costs just 1.3 to 1.5 times a conventional well. At the heart of this improvement is better management of drilling fluids.

The main challenges the mud engineer faces in horizontal drilling are wellbore stability and cuttings removal. Wellbore stability depends on maintaining a chemical and physical balance between formation and mud. Chemical stability in a horizontal wellbore is no different from that in a vertical well. But physical stability becomes progressively more precarious as deviation increases and is most critical when the borehole becomes horizontal. As deviation increases, the wellbore increasingly bears the earth’s vertical stress—in contrast to the horizontal stress born by a vertical well. A heavier mud is needed to prevent hole collapse, evidenced at the surface by curve-shaped cuttings. But then, fracturing and lost circulation become more likely. As wellbore collapse pressure approaches that of the fracture gradient (above) the mud engineer must maintain mud weight somewhere in between.

During planning, the mud engineer can estimate this safe mud-weight window by reviewing offset well logs and fracture gradient data, and noting local experience with lost circulation and tight hole. Core analysis giving in-situ stress would also be used if available. A continuous prediction versus depth of the safety margin is provided by the Mechanical Stability (MSL) log, which estimates wellbore stresses and associated failure related to hole angle from compressional and shear sonic, formation density and gamma ray logs run in nearby wells (see "Horizontal Drilling Comes of Age," page 22).
Drillers must ensure that the equivalent circulating density (ECD), as well as its static density, is within safe limits. ECD, the effective density of a moving fluid, is slightly more than static density because of the friction pressure drop in the annulus. ECD depends on pump rate and fluid viscosity. Since pump rates are generally high in horizontal wells to clean hole, maintaining ECD within limits means keeping viscosity low. The main cause of elevated viscosity is low-gravity solids, so the mud engineer must carefully monitor the solids control equipment and ensure low-gravity solids are kept to a minimum.

Cuttings removal, the second challenge for the mud engineer in horizontal wells, divides into three phases (above):

- Where hole deviation is less than 25 degrees, the wellbore behaves as if vertical, and laminar mud flow combined with conventional choice of pump rate to get the cuttings moving uphole provides satisfactory hole cleaning.

- At deviations up to about 65 degrees, cuttings may accumulate on the low side of the hole and even slip back down the hole when the pumps stop, causing stuck pipe. This section is the most difficult to clean, requiring turbulent flow and annular velocities from 200 to 250 feet (60 to 75 meters) per minute. In unconsolidated formations that erode under constant turbulent flow, hole cleaning can be ensured by intermittently injecting low-viscosity pills of mud into an otherwise mostly laminar circulation. The low-viscosity pill, made by adding dispersant to mud, promotes local turbulent flow.

- At hole deviations greater than 65 degrees, cuttings accumulate on the low side of the borehole but do not slip. Larger cuttings settle first and are harder to move. Turbulent flow combined with pipe rotation is the most effective method of churning up the cuttings bed and cleaning the hole.

In the planning stage, the mud engineer gathers all available facts about the hole, such as bit sizes, casing depths and well profile and also about the formation—its mechanical integrity and pore pressure. This permits calculating mud rheology and flow rate needed to keep the hole clean in the three sections, laminar in the top section and turbulent in the bottom two. Mud rheology at downhole temperature and pressure may be tested in the laboratory.

During drilling, the mud engineer uses several techniques to check how well the hole is being cleaned. In one technique, hole-cleaning efficiency is estimated by measuring the discharge from the solids control equipment and comparing it with what would be expected given the hole size and the rate of penetration. This material balance approach works only for long sections of the well; otherwise the uncertainty in hole diameter leads to inaccuracies.

In another technique, the hole-cleaning performance of a turbulent pill is monitored by measuring the pill’s rheology when it returns to surface. The thicker the pill, the more solids it has picked up.

Once a cuttings bed starts forming on the low side of the well, solids control becomes a major challenge for the mud engineer. The cuttings spend more
Cuttings stranded in the horizontal section get ground to fines by the rotating drillpipe.

time in the wellbore and get crushed by the rotating drillpipe into progressively smaller particles (above). These fine particles increase the percentage of low gravity solids and consequently viscosity. To combat increased viscosity, the mud engineer balances two approaches: diluting the mud—an expensive solution because of the cost of base materials and additives—and ensuring that the solids control hardware is equipped to remove fine material. This requires regularly maintained high-performance shale shakers and centrifuges.

Fine solids in the mud also create a thick mudcake, constricting the deviated hole and increasing the possibility of stuck drillpipe—stuck pipe is more likely in a horizontal well than in a vertical well, because of the dramatically larger area of reservoir exposed to the wellbore. The key to controlling mudcake is minimizing filtrate invasion. One way to reduce fluid loss is to minimize hydrostatic pressure using the lowest possible mud weight, but the mud should not be so light as to cause wellbore instability. A good solution is to use a sized weighting material. The solids must be compatible with the formation—for example, acid-soluble calcium carbonate—and have the right size to bridge formation pores.

Also prominent on the agenda for the horizontal mud system is lubricity. Large side forces experienced while drilling at high angles result in greater frictional drag and increased chances of stuck drillpipe. Therefore, best results are achieved with oil-base muds that provide lubricity. If environmental considerations dictate use of water-base muds, special lubricity additives may be needed.

Estimates vary as to how many horizontal wells will be drilled in the future, but all point to a massive increase. Mud management for horizontal wells, therefore, will continue to evolve. —CF

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